PART I

THE OBJECTIVE STUDY OF SUBJECTIVITY

1

What Is Science?

> [T]he logical empiricists sold us an extraordinary bill of goods.
> Taylor, 1980, p. 26

> Science is not hypothetico-deductive. It does have hypotheses, it does make deductions, it does test conjectures, but none of these determine the movement of theory.
> Hacking, 1983, p. 144

In an article titled "What drives scientific research in education?" Shavelson and Towne (2004) note that the debate over how to define social science has gone on for more than 100 years. They try to calm what have become politicized arguments by recommending that scientific inquiry should be defined not by a particular methodology but by a way of posing and answering questions. Summarizing the conclusions of a National Research Council (NRC) committee convened in 2001 by the National Educational Research Policies and Priorities Board, they recommend (see Table 1.1) that all scientific research, in both the natural and the social sciences, should pose significant questions that can be investigated empirically, should be linked to relevant theory, should use methods that permit direct investigation of the questions, should provide a coherent and explicit chain of reasoning to rule out counter-interpretations, should replicate and generalize findings across studies, and should disclose research data and methods to enable and encourage professional scrutiny and critique (see Feuer, Towne, & Shavelson, 2002; Shavelson & Towne, 2002). Overall, "It's the question – not the method – that should drive the design of education research or any other scientific research. That is, investigators ought to design a study to answer the question that they think is important, not fit the question to a convenient or popular design" (Shavelson & Towne, 2004).

These recommendations seem reasonable, and the effort to overcome competition among polarized camps seems admirable. However, the questionable assumptions that underlie their recommendations start to become evident when the NRC committee identifies three fundamental types of questions and the methods they consider most appropriate to answer them (see Table 1.2).

TABLE 1.1. *Key Characteristics of Scientific Research*

Scientific Research Should
Pose significant questions that can be investigated empirically
Link research to relevant theory
Use methods that permit direct investigation of questions
Provide a coherent, explicit chain of reasoning to rule out counterinterpretations
Replicate and generalize findings across studies
Disclose research to encourage professional scrutiny and critique

TABLE 1.2. *NRC's List of Questions, Answers, and Methods*

Questions	Answers	Methods
1. What's happening?	Asks for a description	Case studies
2. Is there a systematic (causal) effect?	Asks for a causal connection: X caused Y	Randomized clinical trials. Quasi-experiments and correlational studies when necessary
3. What is the causal mechanism? *or* How does it work?	Asks for a causal model	Longitudinal studies. Artifact constructions

The three questions are (1) What's happening? (2) Is there a systematic (causal) effect? and (3) What is the causal mechanism, or how does it work? The committee judged that the first type of question is asking for a description, and they recommended that this should be provided by a survey, ethnographic methods, or a case study. The second type of question is asking whether X caused Y. Here the most desirable method is a randomized clinical trial. Quasi-experimental, correlational, or time-series studies may be needed when random assignment is either impractical or unethical, but "logically randomized trials should be the preferred method if they are feasible and ethical to do." The third type of question – how does it work? – asks for identification of the causal mechanism that created a described effect. Here it seems that mixed methods could do the job. (The committee seemed a bit confused here, perhaps because they believed that causal mechanisms can never be directly observed.)

A significant problem with these recommendations, well intended though they undoubtedly are, is that they perpetuate a widely held but incorrect belief that qualitative research can answer only descriptive questions, whereas quantitative research is able to answer explanatory questions, and, in addition, that such questions are always answered by identifying a causal mechanism (see Table 1.3). If this were so, qualitative research would be adequate for

TABLE 1.3. *The Clichéd View of Qualitative and Quantitative Research*

Quantitative Research	Qualitative Research
Provides explanations	Provides only descriptions
Is objective	Is subjective
Studies causes	Studies experiences
Can test hypotheses	Can only generate hypotheses

generating hypotheses, but measurement and experimentation would be needed to *test* these hypotheses. This was indeed the committee's position. Experimentation, they asserted, "is still the single best methodological route to ferreting out systematic relations between actions and outcomes" (Feuer, Towne, & Shavelson, 2002, p. 8). Although they regretted that "the rhetoric of scientifically based research in education seems to denigrate the legitimate role of qualitative methods in elucidating the complexities of teaching, learning, and schooling," they saw this "legitimate role" as a limited one. "When a problem is poorly understood and plausible hypotheses are scant – as is the case in many areas of education – qualitative methods such as ethnographies . . . are necessary to describe complex phenomena, generate models, and reframe questions" (Feuer, Towne, & Shavelson, 2002, p. 8). In other words, qualitative research can *invent* hypotheses but can never *test* them, so it can never provide explanations.

Perhaps it is true that the committee avoided the temptation of allowing method to drive their choice of research design, but their unexamined assumptions about the nature of science led them to a very short list of the types of questions that can be asked. The committee adopted without question the model of scientific research as a process of "hypothesis testing," the application of a "hypothetico-deductive" logic. The basic idea in this model is that science proceeds by taking two steps. First is the speculative step of proposing a hypothesis. Second is the logical step of testing this hypothesis to see whether its predictions hold up. Science builds knowledge, on this account, by systematically testing hypotheses and eliminating those that are found to be false.

The randomized clinical trial has in recent years been called the "gold standard" of research in social science. For example, the U.S. Department of Education considers use of this design the main sign that a study is supported by "strong evidence." In the department's view, "All evidence is NOT created equal" (U.S. Department of Education, n.d.), and the evidence from a randomized clinical trial is much stronger than evidence from other kinds of investigations.

A randomized clinical trial (see Table 1.4) is a comparison of two or more groups to which participants have been randomly assigned. Its purpose is to

TABLE 1.4. *The Elements of a Randomized Clinical Trial*

It evaluates a *treatment* (a medicine, an intervention) intended to change people (improve health, foster learning).
By *comparing* two or more groups, only one of which receives the treatment. The participants are *assigned* randomly to these groups in order to control for unknown variables.
The outcomes are *measured* with appropriate tests and instruments.
The *null hypothesis* is that the treatment has no effect.
No effect means that any differences among the groups in measures of the *dependent variables* are caused by chance alone.
Analysis takes the form of statistical tests to decide how probable it is that the differences are caused by chance alone and thus how *significant* these differences are.

test the hypothesis that some kind of treatment – a drug, a method of teaching, an intervention – makes a measurably significant difference to some characteristic of these groups, the dependent variable. Random assignment means that the groups are most likely to be similar not just on factors that the researcher knows about but also on unknown factors. Ideally neither the participants nor the researchers know who is in the treatment group: this is a "double-blind" trial. Independent (treatment) and dependent (outcome) variables are given "operational definitions": each variable is defined in terms of the operations with which it will be manipulated and/or measured, with appropriate tests or measurement instruments. The results are analyzed statistically to decide how likely it is that the measured differences between the groups are caused by chance alone.

These elements of the randomized clinical trial follow from the assumption that scientific research is a "hypothetico-deductive" process that builds knowledge by systematically testing hypotheses and eliminating those that are found false. The clinical trial is designed to test a specific hypothesis about a treatment. The emphasis on assignment to groups, on operational definition of measurable variables, and on statistical testing reflects assumptions about science and scientific knowledge that have become second nature but should not go unquestioned. These assumptions have a history, though it is one many people have forgotten.

THE LOGICAL POSITIVISM OF THE VIENNA CIRCLE

> For there is but one science, and wherever there is scientific investigation it proceeds ultimately according to the same methods; only we see everything with the greatest clarity in the case of physics, most scientific of all the sciences.
>
> (Hahn, 1933, 1959, p. 147)

TABLE 1.5. *The Logical Positivist View of Science*

Scientific knowledge involves matters of fact, not of value. (Values are merely personal preferences or subjective opinions.)
The goal of science is a network of knowledge statements (a unified theory of everything).
Research is based on measurement and logical inference.
Measurement is the objective application of an instrument.
Observation and theory are distinct.
Scientific method is the same everywhere.
Scientific knowledge accumulates.
Meaningful scientific statements include no metaphysics.
They include only logical propositions and statements of empirical regularities.
Observation provides the elementary statements. Propositional logic combines these to build theoretical statements.

The roots of the hypothesis-testing model of science can be traced back to the start of the 20th century, when a group of scientists, mathematicians, and philosophers formed what they called the Vienna Circle. The group met informally in Vienna during the early 1920s to discuss science and philosophy. Led by Moritz Schlick, they coined the term "logical positivism" (see Table 1.5) to reflect their agreement with the "positive philosophy" of French thinker Auguste Comte (1798–1857). The addition of the word "logical" was intended to signal the importance of formal logic in scientific investigation. As one of them put it, empirical work and logical construction "have now become synthesized for the first time in history" (Neurath, 1938, p. 1). Empiricists like John Locke and David Hume had seen experience as the basis for knowledge. Rationalists like Rene Descartes had instead based knowledge in the human capacity for reason. These disagreements were finally to come to an end, the Vienna Circle believed, because logical positivism defined the roles in science for *both* experience (in the form of measurements) *and* reason (in the form of logic). The logical positivists had been influenced by Immanuel Kant, who, as we shall see in Chapter 7, had proposed that human knowledge of the world draws its content from sensory perception and its form from innate cognitive categories. In logical positivism, logic and mathematics would provide the form, while observations would provide the content. We can see why this reconstruction of science was also called "empirical rationalism" and "logical empiricism" (Hanfling, 1981).

The Reaction to Einstein's Revolution

One of the main reasons the logical positivists believed that a new model of science was needed was the revolutionary new physics of Albert Einstein. At the end of the 19th century, physicists had begun to think their work was finished and that every physical phenomenon had received an adequate scientific explanation. Newtonian physics, whose laws of motion applied with equal accuracy to the flight of an arrow, the rotation of the planets, and the movement of atoms, seemed flawless and complete. His optics, with studies of color, refraction, and reflection, was equally powerful. Although Newton had lectured in the 1670s and 1680s and published his *Principia* (*The Mathematical Principles of Natural Philosophy*) in 1687, in the late 19th century his work was still unsurpassed. It combined, in powerful and compelling ways, detailed empirical observation with mathematical analysis – especially the calculus, which Newton invented (independently of Leibniz). Newton's famous laws of motion and theory of gravity were considered the model for scientific reasoning 200 years after he formulated them. At the start of the 20th century, physicists were confident that they were near the end of their task; the laws of physical nature were almost complete and perfect. New observations of electromagnetic radiation needed to be fitted in, but this was generally thought to present no real problem.

But then Einstein knocked over the Newtonian applecart. His theory of relativity not only predicted empirical phenomena that had not previously been observed but also explained known phenomena that had proved troubling to Newtonian physics. The most famous example was the precession of the perihelion of the planet Mercury: the way the point on the planet's orbit at which it is closest to the sun shifts slightly with each revolution. But much more important than this, Einstein's physics contradicted most of the basic tenets of the Newtonian worldview. Einstein insisted that motion is relative, so that a body moving in one frame of reference may be stationary in another. He proposed, outrageously, that mass changes with velocity (which means that mass is relative, too). The very concept of a frame of reference, fundamental in Einstein's physics, is simply missing from Newtonian physics; Newton's laws were written as though things are observed from nowhere, or perhaps from everywhere. The Newtonian physicist had, without noticing it, adopted a God's-eye view. Such a position, Einstein declared, is impossible.

It is clear why Einstein's new physics shocked the scientific establishment. In the meetings of the Vienna Circle, the chief topic of debate was what had gone wrong with Newtonian science. How could a system of explanation that had seemed so compelling, so complete, and so consistent turn out to have been so wrong in so many ways? One of their conclusions was that Newtonian physics had, despite appearances, included assumptions that were "metaphysical" rather than truly scientific. Central among these was the concept of gravity. In Einstein's physics, gravity is a local phenomenon – it is the way a body follows the path of least energy through space that has been curved by the presence of a mass. In Newton's physics, gravity was something that now seemed mysterious – a force that one body somehow exerted on another across empty space. Action at a distance, with no intermediary: how could that be? This, surely, was metaphysics (see Box 1.1) rather than genuine science!

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More Information

BOX 1.1. *Metaphysics*

Metaphysics is the investigation of the fundamental principles of reality and the nature of being. The term comes from the Greek words μετά (metà) (meaning "beyond" or "after") and φυσικά (physikà) (meaning "physical"). Its first use was based on the order of the texts in published editions of the writing of the Greek philosopher Aristotle (384–322 BC). The chapters on "physics" were followed by chapters on what Aristotle himself called "first philosophy" (Aristotle, 1988).

Ontology is one of the central branches of metaphysics and is the investigation of the types of entities that exist and the relations these entities have. Epistemology is not usually considered part of metaphysics. It is the investigation of the ways people know the world and questions such as what distinguishes knowledge (*episteme*) from mere opinion (*doxa*). Ontology (or metaphysics) and epistemology are together the central pursuits of philosophy.

Science was originally considered to be part of metaphysics, "natural philosophy." Modern science considers the scientific method to be empirical and philosophy to be speculative or purely theoretical, so that many people now consider metaphysics to be something distinct from, and even opposed to, empirical science.

THE RECONSTRUCTION OF SCIENCE

In their effort to put science on a firm footing, the Vienna Circle began to define principles that would prevent this kind of embarrassment in the future: principles for any genuine science. Einstein's theory of relativity seemed to offer important guidelines for the way science ought to be done. Bridgman – who developed the notion of an "operational definition" (Bridgman, 1945) – put it as follows:

> The Relativity Theory of Einstein is the result of, and is resulting in, an increased criticalness with regard to the fundamental concepts of physics. . . . The general goal of criticism should be to make impossible a repetition of the thing that Einstein has done; never again should a discovery of new experimental facts lead to a revision of physical concepts simply because the old concepts had been too naïve. (Bridgman, unpublished manuscript, 1923, cited in Miller, 1962/1983, p. ix)

The reconstruction of science depended on a number of key tasks. The first was to distinguish between statements that were properly formed, or "meaningful," and those that were nonsensical because they referred to metaphysical notions. The criterion here was whether or not a statement could be tested using either empirical or rational procedures. For example, there are clearly ways to test empirically whether “the moon is round,” so such a statement is meaningful. But a statement like “all life is a void” cannot be tested, so it is unscientific and meaningless. References to “absolute” space or time, independent of all observers, were now judged to be meaningless. More surprisingly, causality also was now seen as a metaphysical notion. A theory may make causal claims, but all we can observe empirically are associations of events, so a meaningful hypothesis must refer only to these. Value judgments, both ethical (“killing is wrong”) and aesthetic (“coffee tastes good”), were also considered meaningless unless they could be transformed into factual statements about people’s preferences: “more people say they prefer cheese.”

The next task was to clarify the role of observation in science. The positivists proposed that reports of observable phenomena provided the “protocol sentences” on which all scientific knowledge is based. These simple, basic statements of experience would provide the empirical basis for any science. They could be combined to form more complex statements, but for this to be successful the truth value of the elementary statements needed to be unambiguous. Observations should be self-evidently true, incorrigible; that is to say, requiring no interpretation or prior knowledge:

> The analysis of knowledge leads to the search for the simplest basic sentences upon which further development can rest. We find them in the so-called “protocol sentences,” i.e., short linguistic indications of the immediately observed present. (Von Mises, 1939/1956, p. 368)

A clear and unambiguous language was needed for observation so that empirical data would be as free as possible from personal bias and theoretical contamination. The way to prevent concepts from being naive or metaphysical was to define them “operationally,” in terms of operations of observation and measurement. Einstein’s physics built from very simple and straightforward observations: the reading of clocks, the observation that two bodies coincide, the application of measuring sticks. This was the “empiricist” side of logical empiricism. The other side was the “logical” component. In a genuine science, the basic data must be built inductively into coherent theoretical statements using the laws of formal logic. Logic would provide the language in which “theory becomes a logical short-hand for expressing facts and organizing thoughts about what can be observed” (Hacking, 1983, pp. 169–170). Scientists deal with linguistic statements, not mental states. But natural language is misleading; it is filled with unscientific, metaphysical notions. “It is the oldest experience and the primitive theories derived from them that are preserved in the traditional stock of language” (Von Mises, 1939/1956, p. 368). Formal logic offered a scientific language that would avoid these problems and preserve the truth value of scientific observations.

The rules of formal logic could be used to combine protocol sentences and produce increasingly complicated statements, culminating in the general theoretical statements that are scientific laws. "Starting from single observations, general propositions are set up in a constructive manner as conjectures (the so-called inductive inference)" (Von Mises, 1939/1956, p. 368). The members of the Vienna Circle were impressed by the theory of language that Ludwig Wittgenstein had introduced in his *Tractatus Logico-Philosophicus* (1922). Wittgenstein wrote of "atomic propositions" that "mirror" or "picture" the world. Such propositions – each of them either true or false – can be systematically combined in "truth tables." The truth or falsity of more complex propositions follows logically (i.e., without interpretation) from the truth values of the atomic propositions. All this seemed exactly the kind of combination of the empirical and the rational that the Vienna Circle wanted. But when in 1927 they finally convinced Wittgenstein to meet with them, they realized that his point of view was very different. As we will see in Chapter 3, Wittgenstein himself came to repudiate this view of language as a mirror of reality in his later works, such as his *Philosophical Investigations* (1953). But for the Vienna Circle the central task of philosophy was to analyze the formal language of logic in science, for they considered this the only valid way to talk about knowledge:

> *Philosophy is to be replaced by the philosophy of science* – that is to say by the logical analysis of the concepts and sentences of the sciences, *for the logic of science is nothing other than the logical syntax of the language of science.* (Carnap, 1937/2002, p. xiii, emphasis original)

However, the logical positivists' apparently straightforward proposals immediately led them into disagreements and conflict. Defining meaningful statements and linking observation and theory turned out to be difficult. First, statements about empirical regularities could clearly be tested empirically, but science also contains logical statements, tautologies such as "a bachelor is an unmarried man," which are true by definition. Obviously one wants to consider these meaningful, too, but they cannot be given operational definitions.

The logical positivists originally proposed that the meaning of a scientific statement *is* its method of verification. But this ran into immediate problems: how can a "meaning" be a "method"? What if there is more than one method? So they proposed instead that a meaningful statement is one that *has* a method of verification. But this approach also led to problems. It excluded universal claims: the statement "All swans are white" is impossible to verify but it is hardly meaningless. It excluded historical theoretical statements, such as: "The universe once had a diameter of 1 meter." It excluded speculative counter-factuals, such as: "If the moon were hit by a sufficiently large asteroid, it would collide with the earth." And it excluded hypothetical counterfactuals: